REMARKS/ARGUMENTS

In the specification, paragraph 47 has been amended to correct a typographical error. The title has been amended in response to the Examiner's request for such. The Applicants hereby request reconsideration of the rejected claims.

Specification:

The Examiner suggested that the title of the invention is not descriptive, and required a new title. In response, the Applicants have amended the title to read "High-Speed, High-Sensitivity Charge-Coupled Device With Independent Pixel Control of Charge Collection and Storage."

Rejections of the Claims:

Claims 1-15 and 18-24 were rejected under 35 U.S.C. §103(a) as being unpatentable over Sayag, U.S. Patent No. 5,585,847 (hereinafter "Sayag") in view of Reich et al., U.S. Patent No. 5,270,558 (hereinafter Reich).

Claims 16 and 17 were rejected under 35 U.S.C. §103(a) as being unpatentable over Sayag, U.S. Patent No. 5,585,847, in view of Reich et al., U.S. Patent No. 5,270,558, and further in view of Rao et al., U.S. Patent No. 6,037,822 (hereinafter "Rao").

We first turn to independent claim 1 and its dependent claims 2-9.

One aspect of the invention, as recited in claim 1, is a charge-coupled device imager including an array of super pixels disposed in a semiconductor substrate having a surface that is accessible to incident illumination. For each super pixel there is provided a plurality of subpixels. Each subpixel corresponds

to an image frame in a sequence of image frames to be imaged. Each subpixel includes a doped photogenerated charge collection channel region opposite the illumination-accessible substrate surface, a charge collection channel region control electrode, doped charge drain regions adjacent to the channel region, a charge drain region control electrode, and a doped charge collection control layer.

The charge collection channel region, the charge drain regions, and the charge collection control layer of each subpixel are characterized by a dopant type and dopant concentration for expanding the charge collection channel region in response to a charge collection control voltage applied to the channel region control electrode. These dopant profiles are selected to collect, in the charge collection channel region, photogenerated charge from the substrate during the image frame corresponding to that subpixel.

These dopant profiles are further selected for contracting the collection channel region in response to a charge storage control voltage applied to the channel region control electrode, to store the collected photogenerated charge in the charge collection channel region and collect substantially no additional photogenerated charge as other subpixels of the super pixel collect photogenerated charge corresponding to other frames of the image frame sequence.

The Examiner suggested that Sayag teaches a charge-coupled imager for imaging a sequence of image frames, pointing to Sayag Fig. 7 as illustrating an array of super pixels disposed in a semiconductor substrate having a surface that is accessible to incident illumination. Each of Sayag's super pixels was said by the Examiner to have a plurality of independently-controlled sub-pixels. Three electrodes were said to be supplied by Sayag, corresponding to three-phase photogenerated charge collection. The Applicants agree with this description of Sayag, with the exception of the Examiner's characterization of image frame collection by Sayag. Sayag acquires a sequence of different "color portions" of a

single image, not a sequence of images, as suggested by the Examiner. Sayag does not consider collecting a sequence of image frames, but instead, different "color portions" of one image frame.

The Applicants respectfully submit that the Examiner's suggestion of Sayag's charge-coupled imager being similar to that of the invention is misplaced. Such is not the case. The distinction between the Sayag imager and the imager of the invention is straightforward and clear. Sayag employs a very specific subpixel arrangement and a configuration of twelve "clock lines" for collecting charge in <u>all</u> sub-pixels during <u>every</u> "color portion" of an image exposure and then manipulating charge among the subpixels as the image portions are acquired. Specifically, "charge generated within...sub-pixels during an exposure sequence is rearranged during the exposure sequence," (Col. 5, lines 39-41).

In direct contrast, in the subpixels of the invention, the dopant type and concentration is tailored so that charge is collected at a given subpixel during a corresponding image frame and is stored at that subpixel's charge collection channel region, with <u>no additional charge collected</u> at that channel region, while other subpixels collect charge corresponding to <u>other</u> frames of the sequence, as recited in claim 1.

Why does Sayag repeatedly store charge in sub-pixels and transfer charge between sub-pixels? To solve a very specific problem; namely, to produce charge packets of mixed red-green-blue signals, in a selected proportion, for making a NTSC (broadcasting) signal of an image (Col. 7, lines 41-53). Sayag Fig. 8 well-illustrates this charge collection and transfer configuration (Col. 6, line 32 - Col. 7, line 40). As shown in Fig. 8A, first Sayag's imager is exposed to the "green portion" of an image and all sub-pixels collect charge from that exposure. Then the "green" charge is manipulated between the sub-pixels to produce the configuration in Fig. 8K. Here the collected "green" charge from the green

exposure has been shifted to sub-pixels 1, 4, 5, and 8, leaving sub-pixels 2, 3, 6, and 7 empty.

Then as shown in Sayag Fig. 8L, after exposure of all sub-pixels to a "blue portion" of the image, "blue" charge corresponding to the blue exposure is collected by <u>all</u> sub-pixels. This additional "blue" charge is rearranged between the sub-pixels to produce the configuration in Fig. 8Q, with sub-pixels 1 and 5 now empty. Finally, all sub-pixels are configured to collect "red" charge during exposure to a "red portion" of the image. This results in the final charge collection configuration of Fig. 8R. Sub-pixels 2, 4, 6, and 8 contain all of "green," "blue," and "red" charge; sub-pixels 3 and 7 contain "blue" and "red" charge, and sub-pixels 1 and 5 contain "red" charge. With this arrangement, Sayag asserts that the proportions of the "red," "green," and "blue" charge in selected pixels is of a proportion required for NTSC broadcast display, and further enables production of chrominance signals for broadcast.

Now considering the imager of the invention, as recited in claim 1, each subpixel of the invention corresponds to <u>a</u> frame in a sequence of image frames; there is a one-to-one correspondence between image frames and subpixels. Each subpixel has a charge collection channel region and channel region control electrode, drain regions and a drain region control electrode, and a charge collection control layer in the substrate below the charge collection channel region. These recited regions and the control layer are characterized by dopant type and concentration to respond to control voltages to collect charge in the subpixel's collection channel during the corresponding image frame and to store the collected charge and collect substantially <u>no</u> additional charge as <u>other</u> subpixels collect charge corresponding to other frames in the frame sequence.

Clearly Sayag provides no teaching or even suggestion of this dopant configuration of the invention for enabling each subpixel to collect charge from a corresponding image frame and store that charge, without further charge

collection, while other sub-pixels collect charge. All of Sayag's sub-pixels collect charge during every color portion exposure of an image. Thus, even if one were to consider Sayag's "color portions" of a single image as image frames, Sayag's correspondence of every sub-pixel to every color portions is in direct contradiction to the requirements of the claims.

Further considering the Sayag imager structure, Sayag does not teach or suggest subpixel charge drain regions and control electrodes; Sayag does not teach or suggest a subpixel charge collection control layer; and Sayag does not teach or suggest dopant concentrations for expanding a charge collection channel region to collect charge during a corresponding image frame and for contracting the channel region to store the collected charge and collect substantially no additional charge as other subpixels collect charge corresponding to other image frames.

The Examiner agreed that Sayag does not disclose a doped charge collection control layer, and refers to Reich for that teaching. The Examiner goes on to assert that Reich teaches a charge collection channel, a channel region control electrode, drain regions, and a drain region control electrode. The Applicants agree that Reich teaches such. However, there is no proper or even operable combination of the Reich and Sayag configurations, and even if one could make the combination, such would still fail to provide the claimed requirement of dopant for producing a subpixel channel region to store collected charge from a corresponding image frame and collect substantially no additional charge as other subpixels collect charge corresponding to other image frames.

The Reich imager is configured such that each and every pixel in the Reich imager is controlled to collect charge simultaneously, i.e., the pixels all collect charge together, during a single image exposure. Each pixel is configured with an electronic shutter. When the pixel shutters are open, charge is collected by all pixels. When the pixel shutters are closed, simultaneously, charge collection is

halted (Col. 5, lines 52-Col. 6, line 3). When charge collection is halted, the charge from each pixel is transferred to a frame store region of the imager (Col. 6, lines 4-12). The use of the electronic shutters inhibits so-called image smear as the pixel charge is transferred to the frame store region of the imager.

There is absolutely no motivation for combining Reich's electronic shutter with Sayag's red-green-blue NTSC imager. Sayag requires that all sub-pixels be exposed to each of the red, green and blue color portion exposures. If one were to use the Reich electronic shutter to somehow "close" selected pixels during one or more of the red-green-blue Sayag exposures, Sayag could not acquire and apportion the needed red-green-blue charge between the subpixels for producing an NTSC signal. Sayag absolutely requires that all sub-pixels correspond to every image exposure.

Further, in the Reich system, once a shutter is closed, charge from all pixels is transferred to a frame store. But Sayag requires that charge be rearranged between subpixels and then maintained at those subpixels as more charge is added to the collected charge. Reich's charge transfer does not allow this.

It is well-held that to combine references requires "inquiry into whether there is reason, suggestion, or motivation to make that combination," *Pro-Mold and Tool Co., v. Great Lakes Plastics, Inc.*, 75 F.3d 1568, 37 USPQ2d 1626 (fed. Cir. 1996). Clearly there is no motivation to combine the Sayag and Reich references. The combination would result in an inoperable system that would not enable the red-green-blue charge collection required by Sayag. The MPEP at 2143.02 makes clear that the altered, inoperable configuration that would be imposed on the Sayag system by a combination with Reich eliminates the possibility of that combination: "If the proposed modification or combination of the prior art would <u>change</u> the principle of operation of the prior art invention being modified then the teachings of the references are not sufficient to rend the

claims *prima facie* obvious," *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959).

Even if one were to combine the teachings of Reich and Sayag for the sake of argument, the combination fails to provide the claimed requirements. Reich requires that all pixels collect charge simultaneously, and teaches this configuration for a single exposure. Sayag requires that all sub-pixels collect charge simultaneously during an exposure. Neither Reich, nor Sayag, nor any combination of the two teaches or even suggests how one might make a one-to-one correspondence between subpixels and image frames, with subpixel dopant concentrations set so that charge is collected during a corresponding image frame and that charge is stored, with no additional charge is collected, as other subpixels collect charge during other image frames as required by the claims.

The Examiner suggested that because the Reich imager enables faster switching times, it would be obvious to use the Reich charge collection control layer in the substrate of the Sayag device. Even if the Reich charge collection control layer enabled faster switching times in the Sayag device, the combination still fails to meet the one-to-one charge collection and storage correspondence between subpixels and image frames required by the claims. Both Sayag and Reich control imager pixel arrays so that each and every pixel (or sub-pixel) collects charge during each exposure. Reich applies an electronic shutter across an entire imager of pixels that simultaneously collect charge; "closing" of the shutter enables charge transfer from the imager without image smear. Sayag requires collection of "red," "green," and "blue" charge by all subpixels so that a selected proportion of charge can be produced in sub-pixels. There is simply no teaching or suggestion by Sayag, by Reich, or by any combination of the two, for producing subpixels within a super pixel having dopant concentrations to store collected charge from an image frame and to collect substantially no additional charge as other subpixels are controlled to collect charge corresponding to other

image frames as required by claim 1. The Applicants therefore submit that the invention claim 1 is not obvious in view of Sayag and Reich.

Claims 2-9 all depend from claim 1 and require the limitations just discussed with regard to claim 1. Although Reich describes the structure similar to that required by claims 2-9, Reich and Sayag both fail, as described above, to teach or even suggest the limitations required by claim 1. The Applicants therefore submit that like the invention of claim 1, the inventions of claims 2-9 are not obvious in view of Sayag and Reich.

Turning now to independent claim 10, like claim 1, claim 10 requires a charge-coupled device imager including an array of super pixels disposed in a semiconductor substrate having a surface that is accessible to incident illumination. For each super pixel there is provided a plurality of subpixels. As with claim 1, claim 10 requires that each subpixel correspond to a frame in a sequence of image frames to be imaged. Each subpixel includes a doped photogenerated charge collection channel region opposite the illumination-accessible substrate surface, a charge collection channel region control electrode, doped charge drain regions adjacent to the channel region, a charge drain region control electrode, and a doped charge collection control layer.

Claim 10 further requires that there be provided a channel region control voltage connection to each subpixel on a substrate surface opposite the illumination-accessible surface. Each such subpixel channel region control voltage connection is configured for independent collection and storage of photogenerated charge from the substrate at the charge collection channel region of a subpixel during a corresponding frame in the sequence of image frames.

As explained above, neither Reich, nor Sayag, nor any combination of the two teaches or even suggests how one might make a one-to-one correspondence between subpixels and image frames. Reich requires that all pixels collect charge simultaneously during an exposure. Sayag requires that all sub-pixels collect

charge simultaneously during an exposure. No subpixel channel region control voltage connection is provided by either Sayag or Reich for independent collection and storage of charge during a corresponding image frame as required by claim 10. Both Reich and Sayag provide connections that require simultaneous, not independent, collection and storage of charge, in complete opposition to the requirements of claim 10. The discussion with regard to claim 1 above is thus equally applicable with regard to claim 10; there can be no proper combination of Reich and Sayag, and any combination of the two fails to provide the independent collection and storage of charge required by the claims. The Applicants submit that the invention of claim 10 is not made obvious by Sayag and Reich.

Claim 11 depends from claim 10 and requires the limitations just discussed with regard to claim 10. Although Reich describes a drain region control voltage connection similar to that required by claim 10, Reich and Sayag both fail to teach or even suggest the limitations of claim 10.

Claim 12 requires a configuration for collection and storage of charge by at least two subpixels during a corresponding frame. The Examiner suggests that at least two Sayag sub-pixels function during a frame. Indeed, as explained above, all of Sayag's sub-pixels collect charge during every color portion exposure. The claims require the exact opposite - that each sub-pixel collect charge only during the one corresponding frame. There is no correspondence between Sayag sub-pixels and color portion exposures so that subpixels independently collect charge only during a corresponding frame, as required by the claims.

The Examiner suggested that Reich describes subpixel-specific weighting of collection and storage of photogenerated charge at each subpixel, as required by claim 13. This is not the case. This subpixel-specific weighting is taught in the instant application, not the Reich reference cited by the Examiner. The Reich reference makes no mention or even a suggestion of such - Reich does not even

suggest a subpixel configuration, let alone weighting of charge collection at subpixels.

Claim 14 requires that the channel region control voltage connection be configured for each subpixel for control of the correspondence between subpixels and image frames. Claim 15 requires that this connection be configured for independent charge collection and storage at a subpixel during a corresponding frame in multiple sequences of image frames. Reich does not teach or even hint at a configuration of subpixels, let alone control of correspondence between subpixels and image frames or multiple sequences of image frames. Reich teaches control of pixel channel regions so that all pixels collect charge simultaneously, during a single image exposure; Reich does not teach how to collect charge from a sequence of image frames and thus it is understandable that Reich does not teach how to make a correspondence between pixels and image frames. There is simply no teaching or suggestion of how one might control subpixels independently to make a one-to-one correspondence with image frames.

As explained previously Sayag likewise does not provide sub-pixel control to corresponding image frames; in Sayag's simple configuration, all of Sayag's sub-pixels collect charge during every image portion exposure, with no independent charge collection and storage as required by the claims. Sayag further fails to teach or even suggest how to collect charge from multiple image frame sequences.

Claims 16-17 require that the channel region control voltage connection be provided as metal control lines, with semiconducting isolation lines provided between the metal control lines, collection channel region control electrodes, and drain control electrodes.

The Examiner suggested that neither Sayag nor Reich teach the use of metal control signal lines, but that Rao, U.S. No. 6,037,822 (hereinafter "Rao") teaches the use of metal for clock signal lines to enable consistent and predictable resistance. Rao employs a metal layer on a back side of a substrate for producing a distributed clock signal network. The invention requires a metal voltage connection to a charge collection channel region. Rao does not teach or even suggest such; Rao is concerned only with depositing metal in trenches on the back side of a substrate. But if, for the sake of argument, one suggests that the Rao backside trench metal configuration could be employed with the Sayag and/or Reich imagers, such a combination would still fail to provide the requirements of claim 10, from which claim 16 depends.

The Examiner further suggested that Reich shows, in Reich Figs. 3-4, the use of isolation lines. The Examiner suggests that such isolation lines are provided by Reich between control signal lines 32, channel region control electrodes 33, and drain control electrodes 34. To be more correct, the Applicants note that Reich reference numeral 32 refers to a "clock electrode," and reference numeral 33 refers to the "gate electrode region," which is connected to all of the pixels, (col. 4, lines 50-52). The reference numeral 34 does refer to drain electrodes as suggested by the Examiner.

Referring to Fig. 2B of the instant application, isolation lines 28 are provided to electrically isolate metal lines 26 from the underlying subpixel gate electrodes. Nowhere does Reich teach or suggest, or at any point illustrate such isolation lines. The Examiner may be referring to dielectric isolation that is common to imager fabrication; such is not the isolation lines required by claim 17. No combination of Sayag, Reich, and/or Rao provides the isolation lines of the invention.

Claims 18-20 require the use of a serial output register and a column binning register in the semiconductor substrate with the imager, for accepting

image frame charge. The Examiner suggested that Sayag discloses the use of a serial output register and a binning register.

Claims 18-20 all depend from claim 10 and require the limitations discussed above with regard to claim 10. Although Sayag describes registers similar to that required by claims 18-20, Reich and Sayag both fail, as described above, to teach or even suggest the limitations required by claim 10. The Applicants therefore submit that like the invention of claim 10, the inventions of claims 18-20 are not obvious in view of Sayag and Reich.

Turning to independent claim 21, like claims 1 and 10, claim 21 requires a charge-coupled device imager including an array of super pixels disposed in a semiconductor substrate having a surface that is accessible to incident illumination. For each super pixel there is provided a plurality of subpixels. Each subpixel corresponds to a frame in a sequence of image frames to be imaged. Each subpixel includes a doped photogenerated charge collection channel region opposite the illumination-accessible substrate surface, a charge collection channel region control electrode, doped charge drain regions adjacent to the channel region, a charge drain region control electrode, and a doped charge collection control layer.

Claim 21 further requires that the number of subpixels included in each super pixel be based on the length of the image frame sequence and the frame rate. With this number of subpixels, charge from each frame in the sequence is collected by at least one corresponding subpixel and stored at that subpixel as other subpixels collect charge from other frames in the sequence.

The Examiner characterized the Sayag passage at col. 5, lines 29++ as describing that in the Sayag system, the number of subpixels and the length of an image frame sequence and image rate can be adjusted and configured. This is not correct. In the cited passage, Sayag explains that signal charge generated within sub-pixels of a super pixel "is rearranged during the exposure sequence,"

(col. 5, lines 39-40). Sayag goes on to explain that the <u>stored charge</u> can be manipulated within a super pixel (col. 5, lines 45-46).

Sayag refers to Figs. 8A-8R to describe this charge manipulation. As described above and shown in Fig. 8A, first Sayag's imager is exposed to the "green portion" of an image and all sub-pixels collect charge from that exposure. Then the "green" charge is manipulated between the sub-pixels to produce the configuration in Fig. 8K. Here the collected "green" charge from the green exposure has been shifted to sub-pixels 1, 4, 5, and 8, leaving sub-pixels 2, 3, 6, and 7 empty. This is the manipulation referred to by Sayag in column 5 of the patent. Sayag explains that "charge packets in adjacent rows can be independently manipulated," (col. 5, lines 62-64). In other words, once charge is collected by all sub-pixels, the collected charge can be manipulated.

As shown in Sayag Fig. 8L, after exposure of all sub-pixels to a "blue portion" of the image, "blue" charge corresponding to the blue exposure is collected by <u>all</u> sub-pixels. This additional "blue" charge is rearranged between the sub-pixels to produce the configuration in Fig. 8Q, with sub-pixels 1 and 5 now empty. Finally, all sub-pixels are configured to collect "red" charge during exposure to a "red portion" of the image. This results in the final charge collection configuration of Fig. 8R. Sub-pixels 2, 4, 6, and 8 contain all of "green," "blue," and "red" charge; sub-pixels 3 and 7 contain "blue" and "red" charge, and sub-pixels 1 and 5 contain "red" charge. With this arrangement, Sayag asserts that the proportions of the "red," "green," and "blue" charge in selected pixels is of a proportion required for NTSC broadcast display, and further enables production of chrominance signals for broadcast. This is what Sayag refers to as the accumulation of charge in selected regions in proportions representative of luminance and chrominance signals (col. 6, lines 22-25).

As discussed above with regard to claims 1 and 10, neither Sayag, nor Reich, considered alone or in any combination, provides the requirements of claim

21. First, Sayag does not select a number of subpixels based on the length of an image frame sequence or frame rate; Sayag does not address image frame sequences at all, instead being concerned with the red, green, and blue portions of a single image frame. In the invention, the length of a frame sequence and the frame rate are considered to provide a sufficient number of subpixels such that all charge in the substrate can be collected during a frame in the time allotted to each frame by the frame rate. Sayag makes absolutely no suggestion of how to make a correspondence between frame rate and number of subpixels. Reich similarly makes no such correspondence; Reich solely teaches collection of charge during a single exposure.

Also as explained previously, neither Sayag nor Reich, nor any combination of the two provides a subpixel configuration that enables a direct correspondence between each subpixel and an image frame; neither enables storage of collected image frame charge at a subpixel as other subpixels collect charge during other frames. Sayag requires that all subpixels collect charge during every color portion exposure - Sayag provides no teaching or even suggestion of how a subpixel could store charge from a selected frame but not collect further charge while other subpixels collect charge during other frames. Reich is concerned with charge collected during a single image exposure and does not teach or suggest how to make any correspondence between subpixels and image frames.

Finally, as explained above, there can be no proper combination of Sayag and Reich, and even if such is made for the sake of argument, the combination fails to provide required subpixel-frame correspondence required by the claims. The Applicants therefore submit that the invention of claim 21, like that of the other claims is not taught or suggested by Sayag and Reich.

Claim 22 requires that the number of subpixels be further based on the charge collection efficiency that is characteristic of photogenerated charge in the

substrate. Claim 23 requires that the number of subpixels be provided to collect and store in a super pixel each frame of an image frame sequence. Claim 24 requires that the number of subpixels corresponding to each frame in an image frame sequence be at least two.

As explained just above, neither Sayag nor Reich, nor any combination of the two provides a subpixel configuration that enables a direct correspondence between each subpixel and an image frame; neither enables storage of collected image frame charge at a subpixel as other subpixels collect charge during other frames. Sayag requires that all subpixels collect charge during every color portion exposure - Sayag provides no teaching or even suggestion of how a subpixel could store charge from a selected frame but not collect further charge while other subpixels collect charge during other frames. Reich is concerned with charge collected during a single image exposure and does not teach or suggest how to make any correspondence between subpixels and image frames.

The Applicants thus respectfully submit that all of the claims are in condition for allowance, which action is requested. If the Examiner has any questions or would like to discuss the claims, he is encouraged to telephone the undersigned Agent directly at his convenience at the phone number given below.

An Information Disclosure Statement accompanies this response.

Respectfully submitted,

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